```
globals
[
   ground-color
   male-fly-color
   female-fly-color
   counter-color

   fly-size
   counter-size

   r-value                          ;;the population growth rate of oriental fruit fly
   infection-rate                   ;;the disease spreading rate

   temp

   count-flies
   average-flies-per-day            ;;count the average amounts of fly per day

   max-fly-stride

   metarhizium-infection-days    ;;time required for M.A. to invade flies
]

breed [flies fly]
breed [counters counter]

turtles-own [stride metarhizium-countdown infected? male? female-mated? female-
fly-lay-egg-count]

to setup
   clear-all

   set-patch-size 4                 ;;set pixel-size with 1*1 m*m/per patch

   set ground-color (brown)
   set male-fly-color (blue)
   set female-fly-color (yellow)
   set counter-color (black)
```

```
  set fly-size 2
  set counter-size 5

  set r-value 0.17
  set infection-rate 0.42

  set temp 1

  set count-flies 0
  set average-flies-per-day 0

  set metarhizium-infection-days 2

  set max-fly-stride 8

  set-default-shape flies "butterfly"
  set-default-shape counters "house"

  if(M.A.switch = true)[add-counters]
  add-flies
  add-ground

  reset-ticks
end

to add-ground
  ask patches [
    set pcolor ground-color
  ]
end

to add-counters
  create-counters 1 [
    set color counter-color
    set size counter-size
    set stride 0
    setxy -35.36 -35.36
```

```
  ]
  create-counters 1 [
    set color counter-color
    set size counter-size
    set stride 0
    setxy 35.36 -35.36
  ]
  create-counters 1 [
    set color counter-color
    set size counter-size
    set stride 0
    setxy 35.36 35.36
  ]
  create-counters 1 [
    set color counter-color
    set size counter-size
    set stride 0
    setxy -35.36 35.36
  ]
end

to add-flies
  create-flies fly-initial-amount / 2 [
    set color male-fly-color
    set size fly-size
    set stride max-fly-stride
    set metarhizium-countdown metarhizium-infection-days
    set infected? false
    set male? true
    setxy random world-width random world-height
  ]
  create-flies fly-initial-amount / 2 [
    set color female-fly-color
    set size fly-size
    set stride max-fly-stride
    set metarhizium-countdown metarhizium-infection-days
    set infected? false
    set male? false
```

```
      set female-fly-lay-egg-count 0
      ifelse(random-float 1.0 <= 0.5) [set female-mated? true][set female-mated?
false]
      setxy random world-width random world-height
   ]
end

to metarhizium-infection
   if(M.A.switch = true)[
      set infected? true
   ]
end

to move-male-fly
   ifelse(M.A.switch = true)[
    ifelse (((distancexy 35.36 35.36) <= infective-distance) or ((distancexy -35.36 -
35.36) <= infective-distance) or((distancexy 35.36 -35.36) <= infective-distance) or
((distancexy -35.36 35.36) <= infective-distance))[
        if (((distancexy 35.36 35.36) <= (distancexy -35.36 35.36)) and ((distancexy
35.36 35.36) <= (distancexy 35.36 -35.36)) and ((distancexy 35.36 35.36) <=
(distancexy 35.36 -35.36))) [
           ifelse (random-float 1.0 <= attraction-rate)[facexy 35.36 35.36][rt random
150 - random 50]
           ]
        if (((distancexy 35.36 -35.36) <= (distancexy 35.36 35.36)) and ((distancexy
35.36 -35.36) <= (distancexy -35.36 -35.36)) and ((distancexy 35.36 -35.36) <=
(distancexy -35.36 35.36))) [
           ifelse (random-float 1.0 <= attraction-rate)[facexy 35.36 -35.36][rt random
150 - random 50]
           ]
        if (((distancexy -35.36 -35.36) <= (distancexy -35.36 35.36)) and ((distancexy -
35.36 -35.36) <= (distancexy 35.36 -35.36)) and ((distancexy -35.36 -35.36) <=
(distancexy 35.36 -35.36))) [
           ifelse (random-float 1.0 <= attraction-rate)[facexy -35.36 -35.36][rt random
150 - random 50]
           ]
        if (((distancexy -35.36 35.36) <= (distancexy 35.36 35.36)) and ((distancexy -
35.36 35.36) <= (distancexy 35.36 -35.36)) and ((distancexy -35.36 35.36) <=
```

```
(distancexy -35.36 -35.36))) [
            ifelse (random-float 1.0 <= attraction-rate)[facexy -35.36 35.36][rt random
150 - random 50]
            ]
        fd random-float stride
    ]
    [ rt random 50 - random 50
        fd random-float stride
        ]
    if(((distancexy 35.36 35.36) <= 10) or ((distancexy -35.36 -35.36) <= 10)
or((distancexy 35.36 -35.36) <= 10) or((distancexy -35.36 35.36) <=
10))[               ;;range within which flies are assumed to be trapped
        metarhizium-infection
    ]
  ]
  [
     rt random 50 - random 50
      fd random-float stride
  ]
end

to move-female-fly
  rt random 50 - random 50
  fd random-float stride
end

to flies-mate
  let infected-total (infection-rate * count flies with [infected? = true] * count flies
with [infected? = false] / count flies)
  ask n-of infected-total flies [metarhizium-infection]
end

to natural-death
  let death (r-value * temp * temp / base)
  ask n-of death flies[die]
end

to reproduce
```

```
  let max-offspring (r-value * temp)
  let male-offspring (max-offspring / 2 - max-offspring / 10 + 2 * random (max-
offspring / 10))          ;;assuming a random fluctuation on number of offspring
  let female-offspring (max-offspring / 2 - max-offspring / 10 + 2 * random (max-
offspring / 10))       ;;assuming a random fluctuation on number of offspring
    create-flies male-offspring [
      set color male-fly-color
      set size fly-size
      set stride max-fly-stride
      set metarhizium-countdown metarhizium-infection-days
      set infected? false
      set male? true
      setxy random world-width random world-height
  ]
    create-flies female-offspring [
      set color female-fly-color
      set size fly-size
      set stride max-fly-stride
      set metarhizium-countdown metarhizium-infection-days
      set infected? false
      set male? false
      set female-fly-lay-egg-count 0
      set female-mated? false
      setxy random world-width random world-height
  ]
end

to go
  if ticks >= 100 [stop]
  if(M.A.switch = true and count counters < 4)[add-counters]
  if(M.A.switch = false)[ask counters [die]]
  set count-flies (count flies + count-flies)
  if(ticks > 0)[set average-flies-per-day (count-flies / ticks)]
  ask flies with [male? = true][
     move-male-fly
     if(infected? = true)[
        set metarhizium-countdown metarhizium-countdown - 1
     ]
```

```
        if(metarhizium-countdown <= 0)[die]
    ]
    ask flies with [male? = false][
        move-female-fly
        if(infected? = true)[
            set metarhizium-countdown metarhizium-countdown - 1
        ]
        if(metarhizium-countdown <= 0)[die]
    ]
    set temp (count flies)
    if(M.A.switch = true)[flies-mate]
    reproduce
    natural-death
    tick
end
```